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REPORT



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OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE	3. REPORT TYPE AND DATES COVERED ANNUAL 15 Jun 92 TO 14 Jun 93
4. TITLE AND SUBTITLE FY91 AASERT - SPATIO-TEMPORAL MASKING IN HUMAN VISION AND ITS APPLICATION TO IMAGE CODING			5. FUNDING NUMBERS F49620-92-J-0359 61103D 3484 S4
6. AUTHOR(S) Dr Stanley A. Klein			
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NL 110 Duncan Avenue, Suite B115 Bolling AFB DC 20332-0001  Dr John F. Tangney			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited			12b. DISTRIBUTION CODE DTIC ELECTE SEP 01 1993 S B D

93-20319  
428

## 13. ABSTRACT (Maximum 200 words)

We measured the temporal dynamics of relative motion judgement. Two lines or dots oscillated either in the same phase of motion, or in 180 phase relative to each other. Subjects were required to discriminate between the two kinds of motion. The dots either oscillated vertically or horizontally. The former case produced oscillating orientation and the later case produced oscillating separation. The temporal frequency of oscillation was varied (presented at OSA-1992). In experiments with lines, the separation of the lines was varied while the distance of the lines from the fovea was held constant. The discriminability of two different phases of relative motion was measured and compared to the detectability of these motions. The psychometric transducer functions were measured and plotted.

03 8 31 03 9

14. SUBJECT TERMS			15. NUMBER OF PAGES
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT (U)	18. SECURITY CLASSIFICATION OF THIS PAGE (U)	19. SECURITY CLASSIFICATION OF ABSTRACT (U)	20. LIMITATION OF ABSTRACT (UL)

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**AASERT Evaluation Report for Grant F49620-92-J-0359**

**Prof. Stanley A. Klein**

**July 22, 1993**

**a) Parent award: AFOSR-89-0238.**

**b) Information about parent award for the 12 months prior to AASERT award:**

**Amount of funding: \$121,855**

**Number of full time equivalent graduate students: 1.5**

**c) Information about parent award for the 12 months after the AASERT award:**

**My AFOSR grant expired one month after the AASERT award started.**

**d) Information about AASERT award for the 12 months after the AASERT award:**

**Amount of funding: \$20,140**

**Number of full time equivalent graduate students: 1.0**

**Number of full time equivalent undergraduate students: 0.0**

**e) I certify that Amnon Silverstein, the student supported by the AASERT asward is a United States citizen. He was born in Detroit.**

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### **Projects this year**

#### **Detection and Discrimination of Relative motion (D.A. Silverstein S.A. Klein to be submitted)**

We measured the temporal dynamics of relative motion judgement. Two lines or dots oscillated either in the same phase of motion, or in 180 phase relative to each other. Subjects were required to discriminate between the two kinds of motion. The dots either oscillated vertically or horizontally. The former case produced oscillating orientation and the later case produced oscillating separation. The temporal frequency of oscillation was varied (presented at OSA-1992). In experiments with lines, the separation of the lines was varied while the distance of the lines from the fovea was held constant. The discriminability of two different phases of relative motion was measured and compared to the detectability of these motions. The psychometric transducer functions were measured and plotted. (Presented ARVO-1993)

#### **Relevance of human vision to JPEG-DCT compression (S.A. Klein, D.A. Silverstein, T. Carney)**

Vision researchers can and should make important contributions to the engineer dominated field of image compression. An overview of the field from the point of view of a vision researcher is presented and several areas for potential scientific contribution are outlined. Presented and published in SPIE, 1992.

#### **A radial pattern for demonstrating MPEG artifacts (D. A. Silverstein, S. A. Klein. Submitted with grant proposal to AFOSR)**

We employed a simple test pattern to test several aspects of MPEG compression. The test sequence was compressed and decompressed using the Stanford Portable Research Group's MPEG codec (PRVG-MPEG). The availability of the source code for this MPEG compressor allows us to have complete control over the processing steps and to obtain intermediate values in the computations. A rotating radial square wave grating was used to induce several kinds of processing artifacts. This test sequence was chosen to have a variety of continuously varying properties. The spatial frequency varies from high at the center to low toward the edge. Eight different angles of edges in both polarities are shown in each frame. The velocity of the edge also varies continuously from the center to the periphery of the figure.

Three experiments were conducted. First, we compressed the 15 frame rotary sequence described previously and watched for artifacts introduced from the codec. The noticeable distortions were the same as we have seen in JPEG compressed images. There were small patches of low-contrast, high-frequency noise around the edges of the sectors. This type of error occurs when the high frequency terms of the DCT are excessively quantized.

In our second experiment, a frame of spatial white noise was introduced in the middle of the sequence. Each pixel value was chosen at random from 256 gray levels. Since the frame immediately after the noise frame could not be predicted from the noise frame and since MPEG streams have limited bandwidth, we might expect that the frame after the noise frame would be more severely degraded than the other frames. This was not the case, however, since the frame after the noise frame could be backwards predicted from the next frame.

In the third experiment, we limited the possibility for backwards prediction by sandwiching two frames of the test pattern between two frames of white noise. This image was substantially more distorted than the previous image. Further, the types of distortion are different. In the image, 16 x 16 pixel blocks (the size of the motion prediction block) of high frequency noise can be seen, particularly in high frequency regions of the image.

From these experiments we can see that perceptual errors are confined to small spatial regions. If these areas of severe errors could be automatically detected, the codec could be improved by changing the bit allocation to provide more information in the severely distorted areas and less information in the areas that were distorted below threshold. Further, by using a simple test pattern, it is easy to see several distinct types of distortions. Other simple test patterns will doubtlessly reveal other types of distortions. Quantifying and cataloging the different types of distortions will facilitate their automatic detection and correction.

#### **A DCT image fidelity metric and its application to a text based scheme for image representation. (D.A. Silverstein, S. A. Klein. Published Proceedings of the SPIE 1993)**

For some types of image fidelity measurements, it is useful to have a very fast, spatially local measurement scheme. The discrete cosine transform (DCT) can be used to transform two images into a space where it is very easy to obtain an estimate of the perceptual distance between two images, that is, how many times threshold the two images are apart.

The DCT can also be localized, which allows a piece-wise comparison of the two images. We used this

algorithm to find the closest fit of an ASCII character (which includes the english alphabet, numbers, punctuation and a few common symbols) to segments of an image. When a digitized grey-scale image is segmented into many rectangular regions and each region is matched with an ASCII character, a page of text is generated that resembles the original image.

The text-image is in a format that can be displayed on a non-graphic terminal and can be sent via electronic mail with the advantage that no further processing is required by the receiver. In addition to image transmission, this processing scheme can be used to preview stored images with a text terminal. For example, if you were not sure if a computer file contained an image you wanted to send to a printer, you could first view the image processed into ASCII characters on your text terminal. Since the algorithm is computational inexpensive, the preview process takes very little time.

#### **Restoration of compressed images (D.A. Silverstein, S.A. Klein To be presented SPIE Feb 93)**

An image that has been compressed and decompressed (codec) by a lossy method becomes distorted. The distortion is usually manifest in some characteristic artifact. For example, the JPEG compression algorithm often introduces a high-frequency 'ringing' artifact around high contrast edges. We have developed a processing algorithm that can eliminate this artifact in many instances.

Our edge restoring method works by first locating the edge. A Sobel transform is used to find the area around the edge. The Sobel transform's output is filtered by first assuming a continuity constraint then by thresholding. This eliminates the spurious edges due to the ringing artifact. The remaining data is fit with either a straight line or a curve by a least squares method. The image is then reconstructed by low pass filtering on either side of the fit edge.

This algorithm, or any other enhancement algorithm, cannot work in all cases. What is noise in one image may be important data in another. Fortunately, in image compression, we have an advantage. Before the image is stored or transmitted, we have access to the original and the distorted versions. The distorted version is processed by our edge enhancement algorithm and compared to the original. For every 8x8 pixel block, it is determined whether the processing reduces the distortion. This determination is either made by a model of human vision or, in our case, directly by a human. For each block, one additional bit is transmitted with the compressed image, indicating whether or not the receiver should apply the enhancement algorithm to that block.

The bit is included in the parity of the image block itself, so a standard decoder will be able to decode the image. A decompressor that knows about the parity code can generate a superior image by applying an enhancement algorithm to the blocks that have been labeled for post processing. Any other post processing algorithm may be used instead of, or in addition to, our edge enhancement algorithm. The procedure may be automated when an appropriate model of human vision is developed, but currently is useful in applications where the cost of a human operator is not prohibitive.